PATENT SPECIFICATION

567,368

Convention Date (Switzerland): Feb. 21, 1942.

Application Date (In United Kingdom): Feb. 18, 1943. No. 2692/43.

Complete Specification Accepted: Feb. 12, 1945.

COMPLETE SPECIFICATION

Improvements in or relating to Rotary Compressors

We, [illegible] ZER FRERES SOCIETE ANONYME [illegible] are formed and these reduce the efficiency [illegible] under the [illegible]

PATENTS AND DESIGNS ACTS. 1907 TO 1942

SPECIFICATION NO. 567, 368

In accordance with the Decision of the Superintending Examiner, acting for the Comptroller-General, dated the twentieth day of September, 1945, this specification has been amended under Section 21 in the following manner:-

Page 1, line 13, *after* "its" *insert* "greatest".

Page 2, line 117, *after* "sound" *insert* "in the medium".

The Patent Office,

15th October, 1945.

D 39934-1 125 D/d 3084 10/45

reducing bending stresses.

In the process of development of centrifugal compressors the pressure ratio per stage has been steadily increased mainly by raising the peripheral velocity of the rotor. The mechanical stressing of the rotors of the centrifugal compressors of the most recent design is very high owing to the peripheral velocity falling within the range of the speed of sound and for this reason such rotors have been made with blades extending in a purely radial direction and with radial flow. As the absolute outlet velocity of the compressed gas, when the direction of the passages between the blades is radial, proves to be even greater than the peripheral velocity of the rotor it lies a considerable amount above the speed of sound in the medium compressed. The use of blades bent backward which were wellknown to reduce the outlet velocity at a different peripheral velocity was abandoned before the speed of sound was reached this course being followed chiefly in view of considerations of strength. The desire for greater peripheral velocities and increased delivery pressures could be realised only by the use of purely radial blades. The increase of the outlet velocity above the speed of sound which thus occurred was put up with as being inevitable. This invention starts from the realisation that with a rise of the velocity of flow above the speed of sound Mach's pressure waves rotates while in a cross-section normal to the axis each blade extends in a radial direction so that the absolute outlet velocity of the medium compressed may not exceed the velocity of sound in that medium to an extent sufficient to give rise to Mach's pressure waves, while at the same time bending stresses are avoided.

If these features are followed the peripheral velocity of the rotor can be raised bove the speed of sound in the compressed medium without impairing the efficiency of the compressor.

The pressure ratio per stage obtainable increases approximately with the square of the peripheral velocity of the rotor so that for example an air compressor running with a peripheral velocity in the neighbourhood of 400 meters per second and higher can secure without difficulty in a single stage a pressure ratio amounting to 2 and over.

A semi-axial form of rotor with backward bent blades has long been known for use in fans. Such rotors made of sheet metal or cast material are however only suitable for low peripheral velocities at which the mechanical stressing of the blades has only an influence of secondary importance in the choice of shape. It is only when the semi-axial rotor is employed in compressors in which the blade peripheral velocity is high and the speed of sound in the compressed medium is reached and exceeded that it becomes

PATENT SPECIFICATION

567,368

Convention Date (Switzerland): Feb. 21, 1942.

Application Date (In United Kingdom): Feb. 18, 1943. No. 2692/43.

Complete Specification Accepted : Feb. 12, 1945.

COMPLETE SPECIFICATION

Improvements in or relating to Rotary Compressors

We, SULZER FRERES SOCIETE ANONYME, a Company organised under the laws of Switzerland, of Winterthur, Switzerland, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to a rotary centrifugal compressor of the type which gives extra high pressure ratios per stage, the impeller having blades integral with the rotor and with at least its circumference rotating at a velocity above the speed of sound in the medium compressed, the blades of the rotor when considered in cross-sections normal to the rotor axis being radially directed with the object of reducing bending stresses.

In the process of development of centrifugal compressors the pressure ratio per stage has been steadily increased mainly by raising the peripheral velocity of the rotor. The mechanical stressing of the rotors of the centrifugal compressors of the most recent design is very high owing to the peripheral velocity falling within the range of the speed of sound and for this reason such rotors have been made with blades extending in a purely radial direction and with radial flow. As the absolute outlet velocity of the compressed gas, when the direction of the passages between the blades is radial, proves to be even greater than the peripheral velocity of the rotor it lies a considerable amount above the speed of sound in the medium compressed. The use of blades bent backward which were wellknown to reduce the outlet velocity at a different peripheral velocity was abandoned before the speed of sound was reached this course being followed chiefly in view of considerations of strength. The desire for greater peripheral velocities and increased delivery pressures could be realised only by the use of purely radial blades. The increase of the outlet velocity above the speed of sound which thus occurred was put up with as being inevitable. This invention starts from the realisation that with a rise of the velocity of flow above the speed of sound Mach's pressure waves are formed and these reduce the efficiency of the compressor more than was previously assumed. The reduction of this efficiency becomes greater as the velocity of flow rises, whereby a limit has hitherto been set to a further increase in the pressure ratio per stage. The present invention now indicates how it is possible to raise the pressure ratio per stage of a centrifugal compressor by a further increase of the peripheral velocity while avoiding the need for putting up with a reduction in efficiency.

According to this invention the blades run obliquely and with an inclination relative to the axis and they are curved from the inlet to the outlet in a direction opposite to that in which the impeller rotates while in a cross-section normal to the axis each blade extends in a radial direction so that the absolute outlet velocity of the medium compressed may not exceed the velocity of sound in that medium to an extent sufficient to give rise to Mach's pressure waves, while at the same time bending stresses are avoided.

If these features are followed the peripheral velocity of the rotor can be raised above the speed of sound in the compressed medium without impairing the efficiency of the compressor.

The pressure ratio per stage obtainable increases approximately with the square of the peripheral velocity of the rotor so that for example an air compressor running with a peripheral velocity in the neighbourhood of 400 meters per second and higher can secure without difficulty in a single stage a pressure ratio amounting to 2 and over.

A semi-axial form of rotor with backward bent blades has long been known for use in fans. Such rotors made of sheet metal or cast material are however only suitable for low peripheral velocities at which the mechanical stressing of the blades has only an influence of secondary importance in the choice of shape. It is only when the semi-axial rotor is employed in compressors in which the blade peripheral velocity is high and the speed of sound in the compressed medium is reached and exceeded that it becomes

[*Price* 1/-]

necessary to avoid bending stresses for the blades and this could only be attained hitherto by the radial arrangement of the blade passages. A rotor designed according to the present invention permits the radial direction of the blade sections to lie normal to the rotor axis, as is necessary for mechanical reasons, and to be combined with a backward curving of the blade passages, which is necessary for reasons of flow technique, and thus the disadvantages with respect to flow which have previously made themselves apparent can be eliminated.

In the semi-axial flow rotor formed according to the invention, intermediate blades may also be arranged or the blades may be discontinuous and staggered. In this way a further improvement in the rotor efficiency is obtained, in so far that it avoids the increased risk of turbulency occurring when the velocity of sound is exceeded.

The invention is illustrated in the accompanying drawings, in which:—

Figure 1 shows diagrammatically and in longitudinal section one example of a construction of high-pressure compressor according to this invention.

Figures 2 and 3 show respectively in end view and in cross-section the rotor of the compressor illustrated in Figure 1.

Figures 4 and 5 are similar views of a rotor having intermediate blades.

Figures 6 and 7 show again similar views of a rotor having discontinuous and staggered blades.

The compressor shown in Figure 1 has a rotor 1 on which are the blades 2 these blades running obliquely and at an inclination with respect to the rotor axis the blades being curved from inlet to outlet in a direction opposite to the direction of rotation 8 of the rotor. The blades are formed integral with the rotor as for instance by milling or forging. The rotor is arranged so that it is overhung on the shaft 3. The degree of obliquity of the passages between the blades 2, that is to say the angle which they form with the axis X and the circumference, may vary from 30° to 60°. The air or other gas is drawn in from the passage 4 and delivered in the compressed state through the spiral casing 5.

In service the blades 2 run with a peripheral speed which exceeds the velocity of sound at least at the outlet edges 6. In order to enable them to support the increased centrifugal force without bending the form and arrangement of the blades 2 are such that their cross-sections in the planes I—I, II—II and III—III (Figure 3) point in the direction of the radii r_1, r_2 and r_3 (Figure 2).

The direction of flow in the passages between the blades is not radial but is inclined with respect to the rotor axis X in the direction of the arrow 7 (Figure 3). In this way it is made possible to bend the blades backwards with respect to the direction of rotation shown by the arrow 8 in Figure 2 so that the absolute velocity of the compressed medium at the outlet does not exceed the velocity of sound.

This backwards bending makes it possible to have a compression ratio of more than 2.0 within a single stage, without having to put up with disturbances through Mach's pressure waves, which occur in the region above the velocity of sound.

The rotor shown in Figures 4 and 5 has additional intermediate blades 9 arranged between the main blades 2. These intermediate blades gives a better guiding to the flow of the medium which is to be compressed and thereby prevent, within the flow passages, a non-uniform distribution of the medium which is to be compressed.

The rotor shown in Figures 6 and 7 has blades 10 which are interrupted at the places 11 and are continued in staggered relation. In this way turbulence, which could occur at the high speeds used, is prevented.

It is possible under certain conditions of working to let the velocity of flow of the compressed medium increase slightly beyond the velocity of sound without any disturbances being caused by Mach's pressure waves.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A centrifugal compressor of the type indicated in which the blades run obliquely and at an inclination with respect to the axis of the rotor being curved in the form of a helix from inlet to outlet in the direction opposite to that in which the rotor rotates so that the absolute outlet velocity of the medium compressed does not exceed the speed of sound so far as to give rise to Mach's pressure waves.

2. A high-pressure rotary compressor as claimed in Claim 1, in which the blades are discontinuous and staggered in order to prevent turbulence.

3. A rotor for a high-pressure rotary compressor as herein described with reference to Figures 1, 2 and 3 or Figures 4 and 5 or Figures 6 and 7 of the accompanying drawings.

Dated this 18th day of February, 1943.

KILBURN & STRODE,
Agents for the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1945.

Fig. 1.

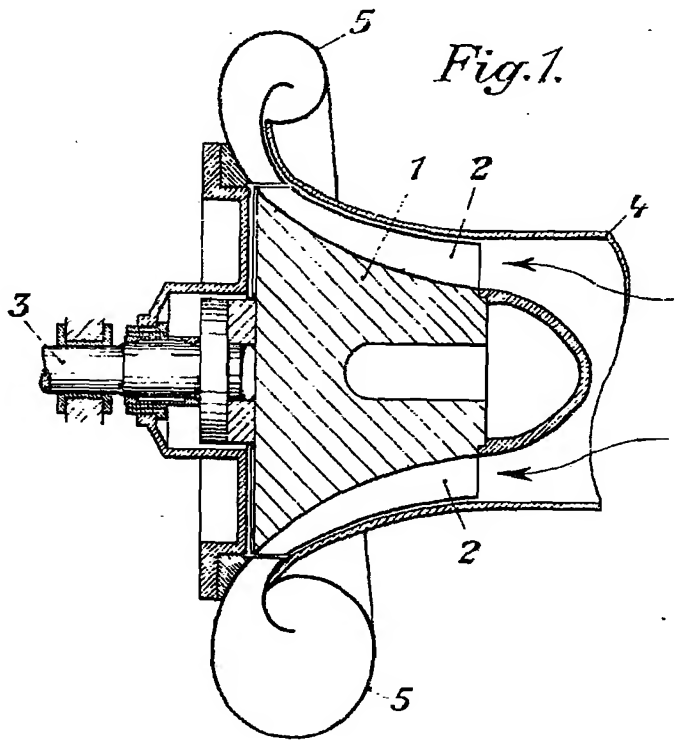


Fig. 2.

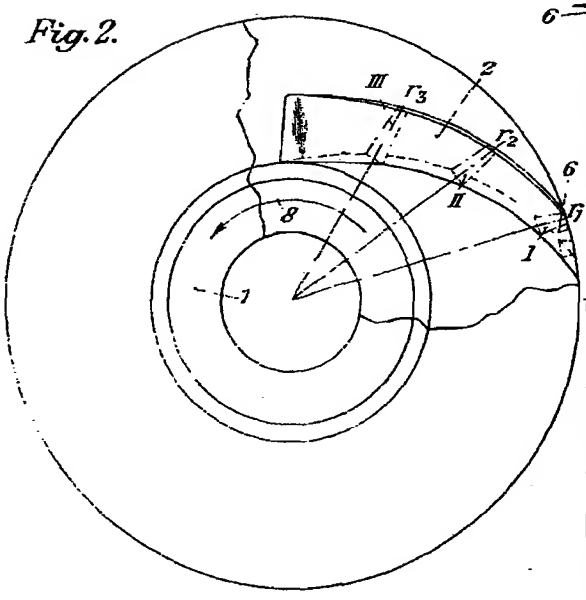


Fig. 3.

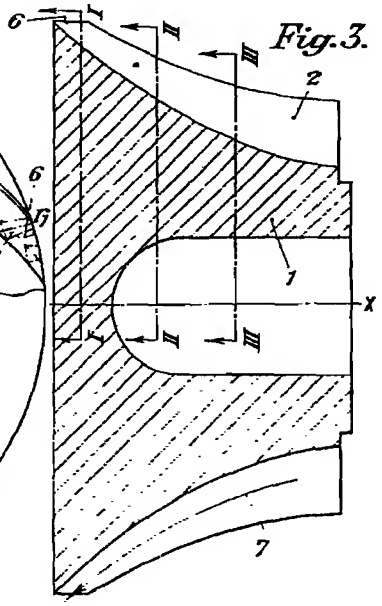


Fig. 4

Fig

Fig. 4.

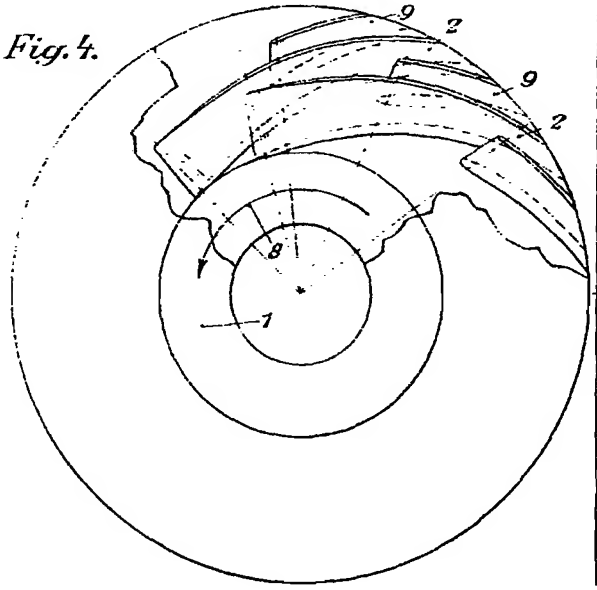


Fig. 5.

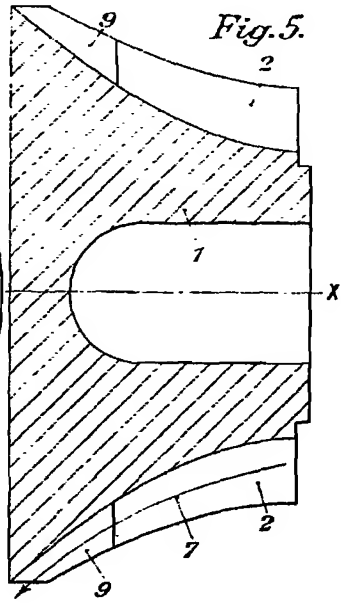


Fig. 3.

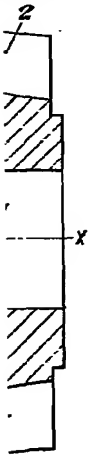


Fig. 6.

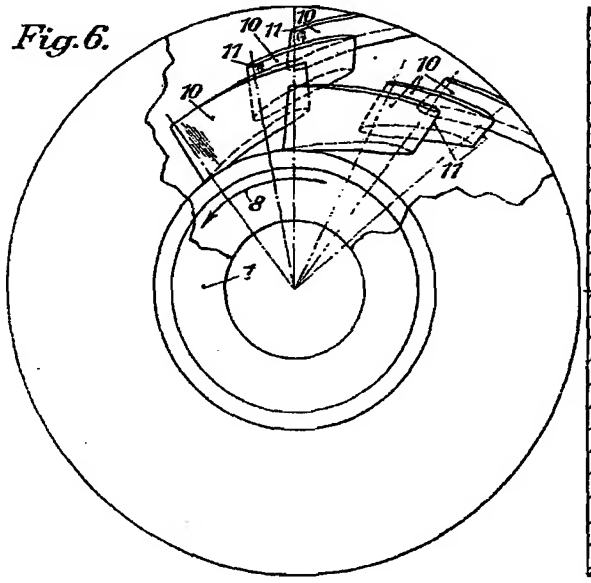
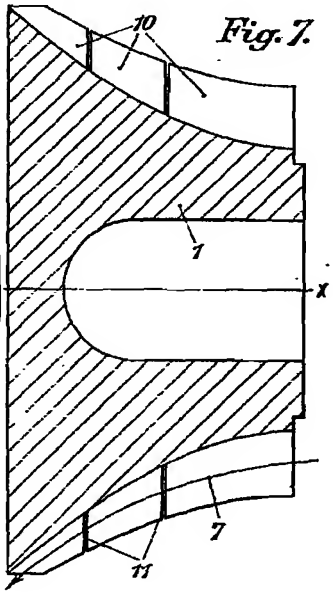


Fig. 7.



Malby & Sons, Photo-Litho

567,368 COMPLETE SPECIFICATION

2 SHEETS
SHEET 1

Fig. 1.

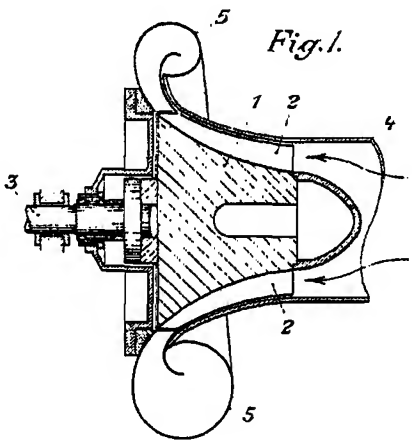


Fig. 2.

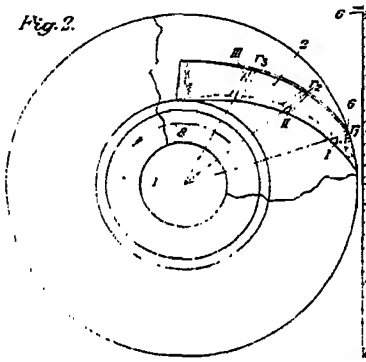
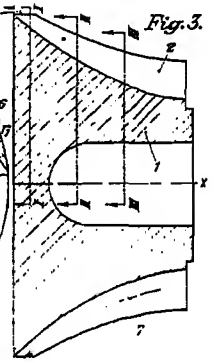


Fig. 3.



SHEET 2

Fig. 4.

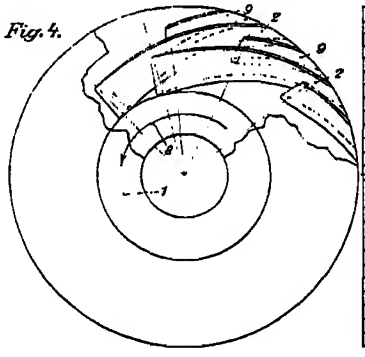


Fig. 5.

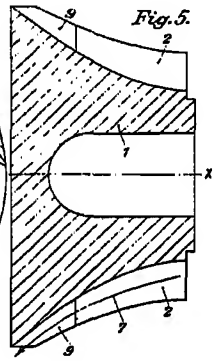


Fig. 6.

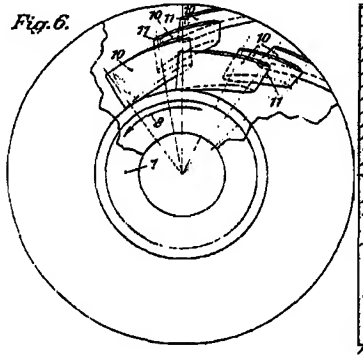
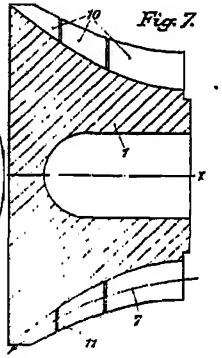


Fig. 7.



Malby & Sons, Photo-Litho